The Alaska Village Energy Model: An Integrated Community Energy Planning Tool

Steve Colt, University of Alaska, 907-786-1753, sgcolt@uaa.alaska.edu
Tobias Schwoerer, University of Alaska, 907-786- 5404, tschwoerer@uaa.alaska.edu

Overview

We have constructed a simple but comprehensive village energy use model that includes space heating and transportation fuel use as well as electricity. Because people in isolated remote northern communities pay about 2/3 of their overall energy bills for heat and transportation (WH Pacific et al. 2012), knowledge of overall energy demand by major end use is important when considering energy systems that can make the best use of efficiency and renewables as resources to offset costly fossil fuels. Previous work (Devine & Baring-Gould 2004) provides community planners and policy makers with a good tool for estimating community electricity demand. This paper builds on that work with an integrated model that can be used to estimate overall village energy usage based on a relatively small number of socioeconomic characteristics, such as population; number of residential, commercial and public facilities; housing and building stock characteristics; and transportation patterns and equipment types. The Alaska Village Energy Model (AVEM) model uses the best available primary data from recent collection efforts, and can easily incorporate new data that may become available.

Methodology

We collected new primary data on transportation and building energy use via a field trip and in-person interviews with 55 households in five remote Alaska communities. We conducted statistical analysis of 1) residential energy retrofit assessments made with the Alaska Housing Finance Corporation's AKWARM model; 2) several hundred benchmarking assessments of rural nonresidential building energy use; and 3) data and estimates from the 2012 Alaska End Use Energy Study (WH Pacific et al. 2012). We incorporated the existing Alaska Electric Load Calculator parameters as lookup tables to compute initial electric loads. Finally, we developed the Alaska Village Energy Model (AVEM) as an Excel worksbook to incorporate all of this information and to project future energy use and cost under a variety of user-specified conditions.

Table 1 shows general model parameters and Table 2 indicates the general level of engineering detail in the model, with four types of housing stock and available choices among methods to specify the how residential space heating intensity (kbtu/ft2) is determined. Nonresidential buildings heating fuel usage is calculated as a linear function of nonresidential electric kWh, or as a function of nonresidential square feet. Local transportation fuel usage is calculated based on annual use per person or per vehicle (snowmachine, boat, and ATV/truck). Air transportation to and from villages is not calculated. Electricity use is modeled as shown in Devine & Baring-Gould (2004).

With a baseline established, the model also accepts anticipated future trends in population, building stock, space and water heat fuel use intensity, and index values for trends in vehicle miles per person and fuel per vehicle-mile. Electric loads can be projected by customer class or by adding specific new loads. Renewable supply sources such as wind can be included as negative loads.

In addition to calculating annual energy use for 30 years, the model also computes energy costs per person and by end use, with trends in future unit prices specified by the user. Greenhouse gas emissions are also calculated using user-specified values for dollars per ton of CO2.

Results

The AVEM model has been beta-tested by staff from the Alaska Energy Authority and can be used by local, regional, or state-level planners to explore options for reducing an entire community's future dependence on diesel and gasoline. The model is available to the public (Colt 2013).

Conclusions

Despite a continuing lack of data on heating and transportation energy use in remote Alaska communities, it is possible to construct integrated models of the energy use by an entire community using existing data and estimated

parameters. Consideration of the entire energy system should allow for better utilization of efficiency as a resource and for more effective integration of intermittent renewable resources into the existing energy supply system.

Table 1. General parameters

Community name		Demonstration	
Population	persons	60	
Start Year		2012	
Real discount rate	% per yr	4.0%	
Heating degree days base 65		16,000	
City for monthly HDD fractions		Dillingham	see "monthly HDD" tab for choices
Population growth	% per yr	1.0%	
Btu per gallon of fuel		134,000	common values 134,000 (#1) 138,000 (#2)

		residential	nonresidential	utility
Price of diesel fuel in Start Year	$/gallon	5.00	4.50	4.00
Price of gasoline in Start Year	$/gallon	6.00		

Table 2. Display of residential space heat intensity setup showing multiple options for calculation

		house group Hgroup1	Hgroup2	Hgroup3	Hgroup4
label for group		single_old	single_new	multi	mobile
house_type (1=SF, 2=MF, 3=MH)		1	1	2	3
number of housing units		15	5	2	0
average square feet	FT2/yr	1,100	1,100	1,000	900
Choose 1 method for space heat intensity kbtu/FT2					
Choice of method (1, 2, 3, 4)		1	2	3	4
Enter required inputs for your method(s)					
1 Linear function of HDD					
input: post-retrofit? (1=yes, 0=no)		0	1	0	0
lookups for linear function	d_multifamily	0	0	1	0
	d_mobilehome	0	0	0	1
result of linear function	kbtu/FT2/yr	95.4	73.9	83.5	126.3
or					
2 kbtu per FT2 by direct entry	kbtu/FT2/yr	0	75	0	0
(consult tables in equations tab)					
or					
3 mmbtu per house per year	mmbtu/H/yr	0	0	100	0
(consult tables in equations tab)					
or	kbtu/FT2/yr	0.0	0.0	100.0	0.0
4 engineering end use approach					
End use baseboard heat per SqFt	kbtu/FT2/yr	40.0	30.0	20.0	50.0
heater efficiency	%	75%	75%	75%	75%
fuel input to heater	kbtu/FT2/yr	53.3	40.0	26.7	66.7
Space heat intensity chosen:	kbtu/FT2/yr	95.4	75.0	100.0	66.7

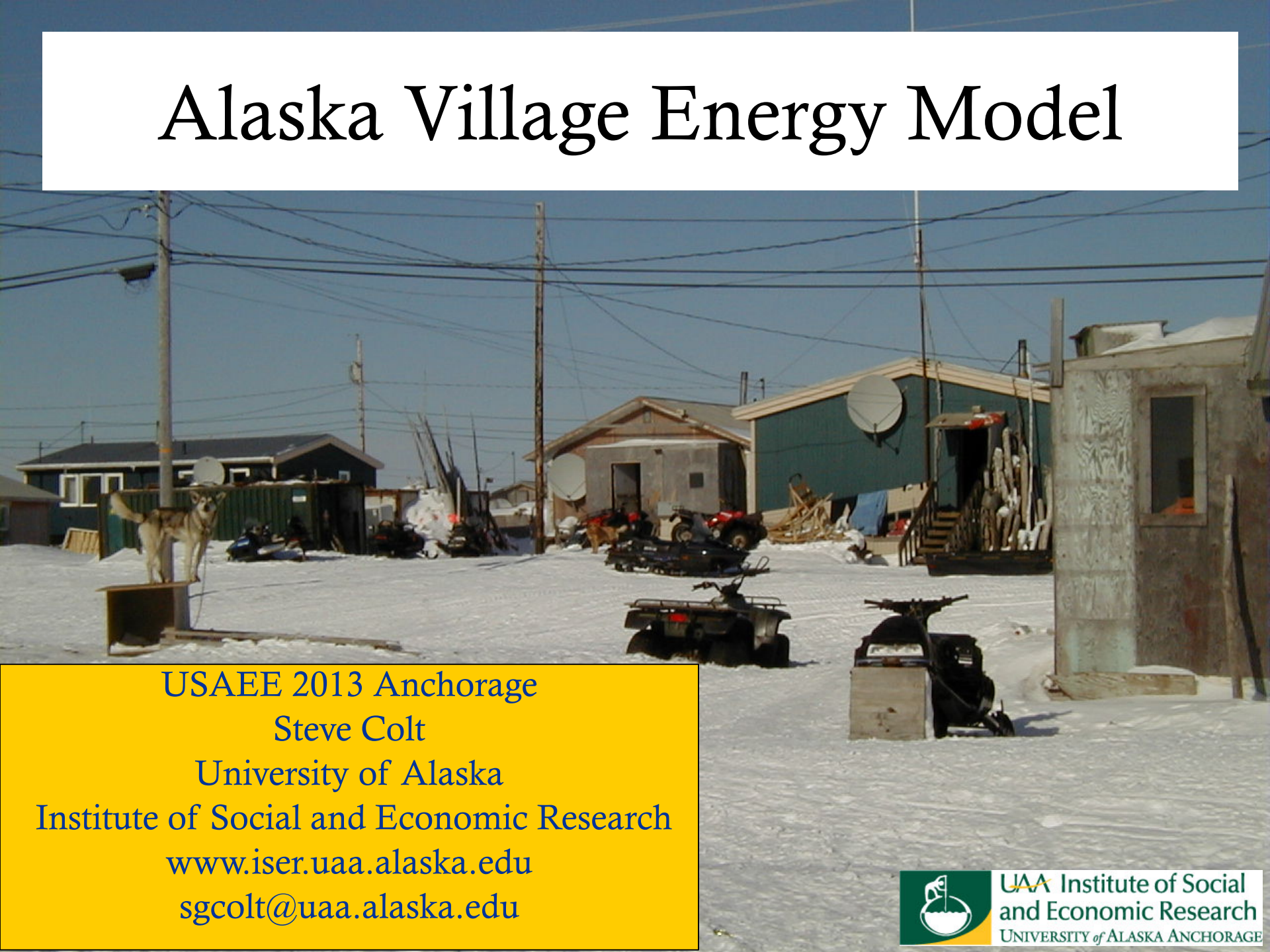
References

Devine, M.; Baring-Gould, E.I. 2004. The The Alaska Village Electric Load Calculator. National Renewable Energy Lab. NREL Technical Report NREL/TP-500-36824. Available at http://www.akenergyauthority.org/Useful%20documents%5CThe-Alaska-Village-Electric-Load-Calculator.pdf

Colt, S. 2013. Alaska Village Energy Model AVEM3.xlsx. Prepared for Alaska Housing Finance Corporation. Available at: http://www.iser.uaa.alaska.edu/people/colt/personal/AVEM3.xlsx

WH Pacific, et al. 2012. Alaska Energy Authority End Use Study End Use Study: 2012. Prepared for Alaska Energy Authority. http://www.akenergyauthority.org/PDF%20files/EndUseStudy2012/AlaskaEndUseStudy2012.pdf

Alaska Village Energy Model



USAEE 2013 Anchorage
Steve Colt
University of Alaska
Institute of Social and Economic Research
www.iser.uaa.alaska.edu
sgcolt@uaa.alaska.edu

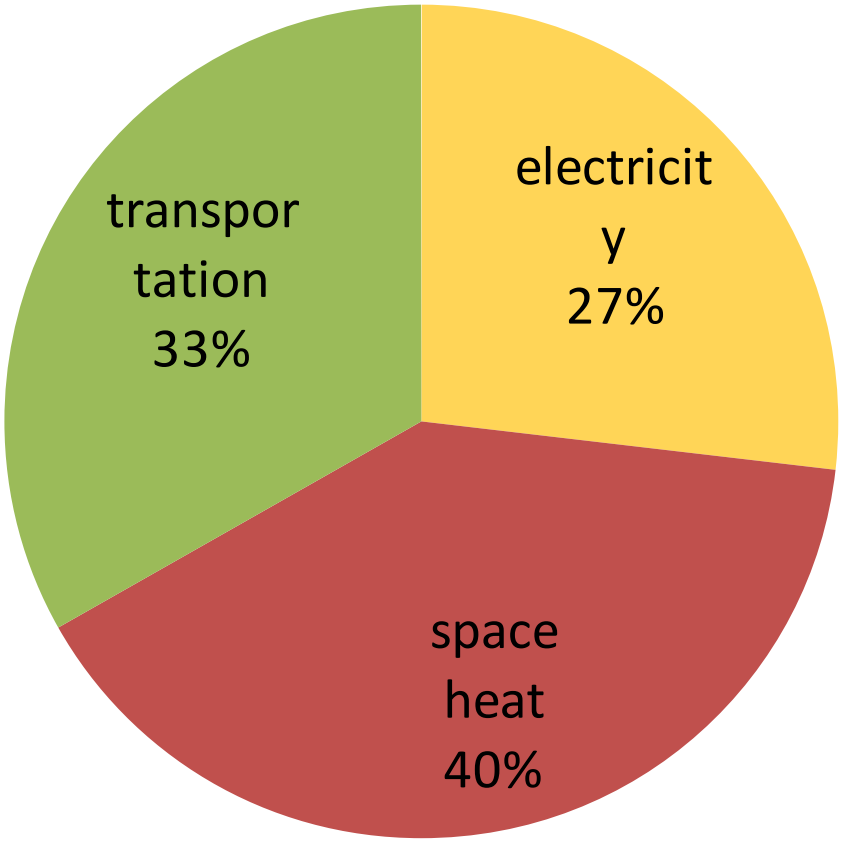
UAA Institute of Social and Economic Research
University of Alaska Anchorage

Electricity from diesel: 110 gal/person/yr residential + 237 gal/person/yr nonres

78,000 people in FY10 PCE communities

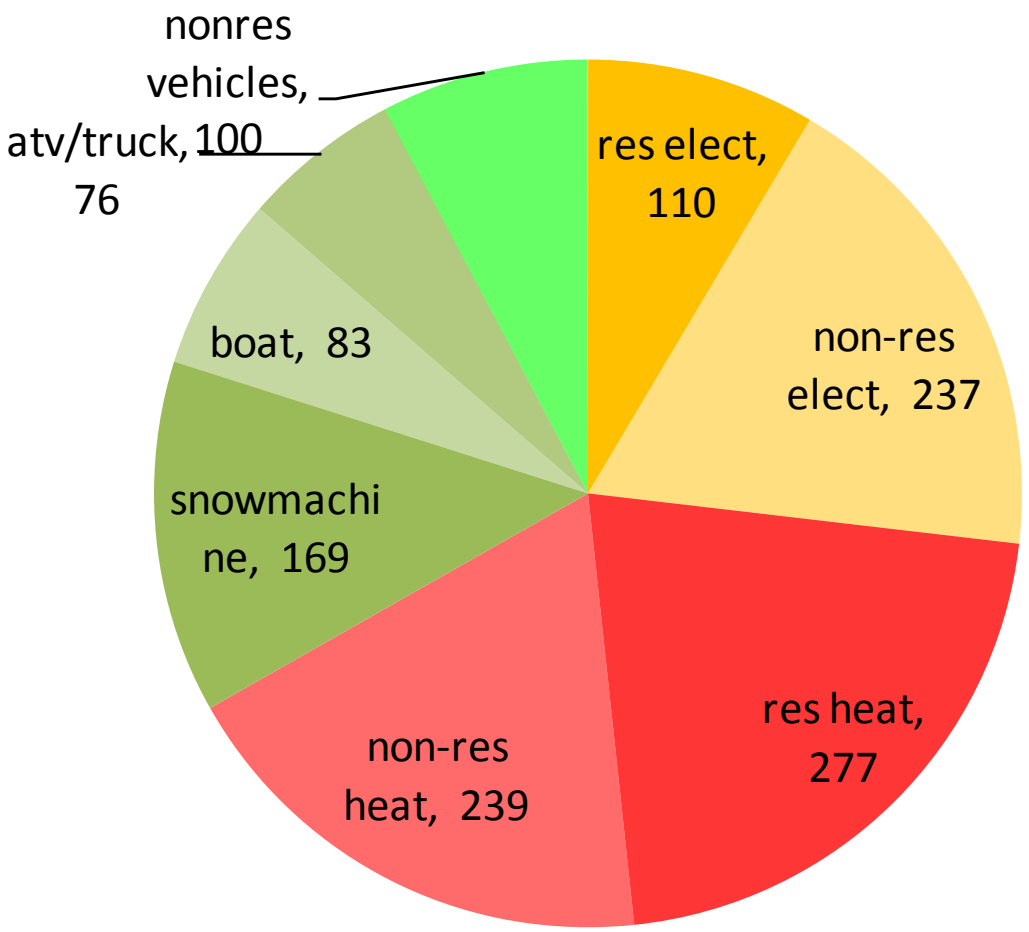
Kwinhagak photo S. Colt

Diesel gallons primary energy per person per yr in rural AK communities



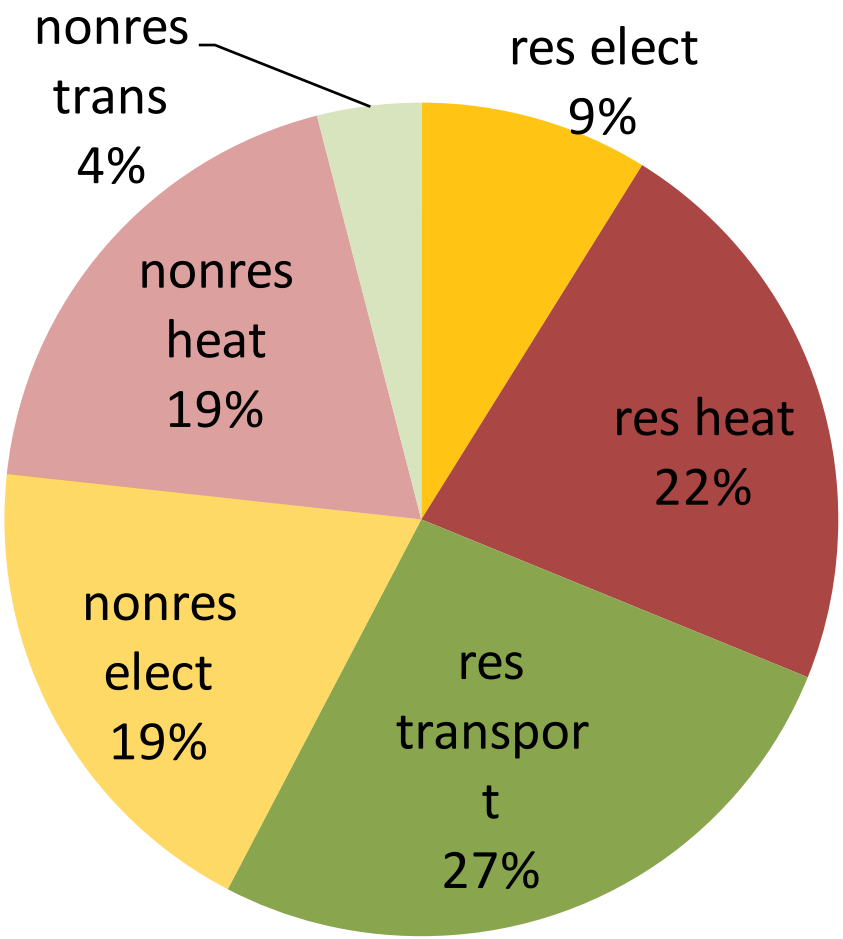
Total 1,250 gallons per person per year

Diesel gallons by end use



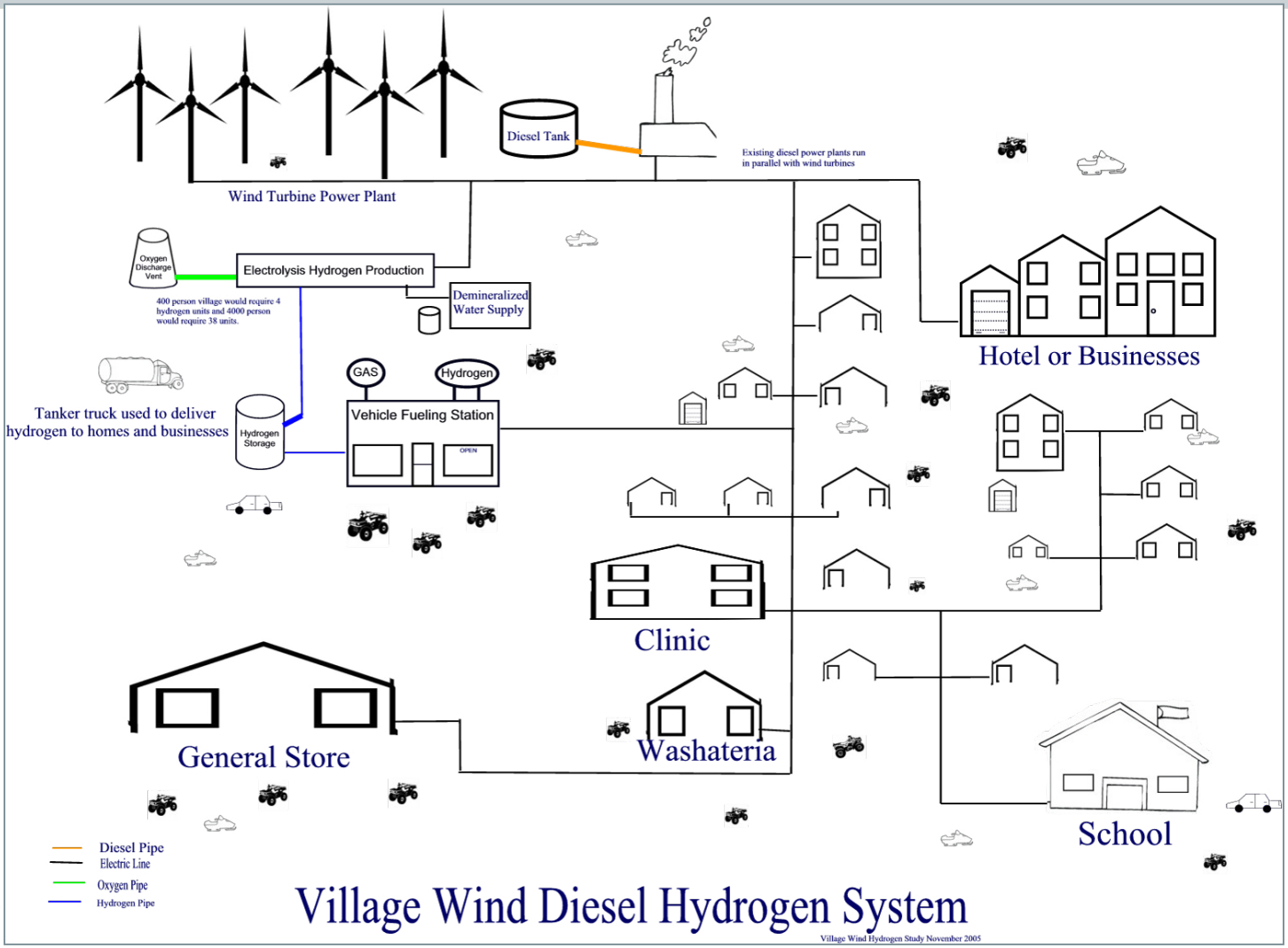
Total 1,250 gallons per person per year

Diesel gallons by consumer type



Total 1,250 gallons per person per year:
716 residential (58%)
526 nonres (42%)

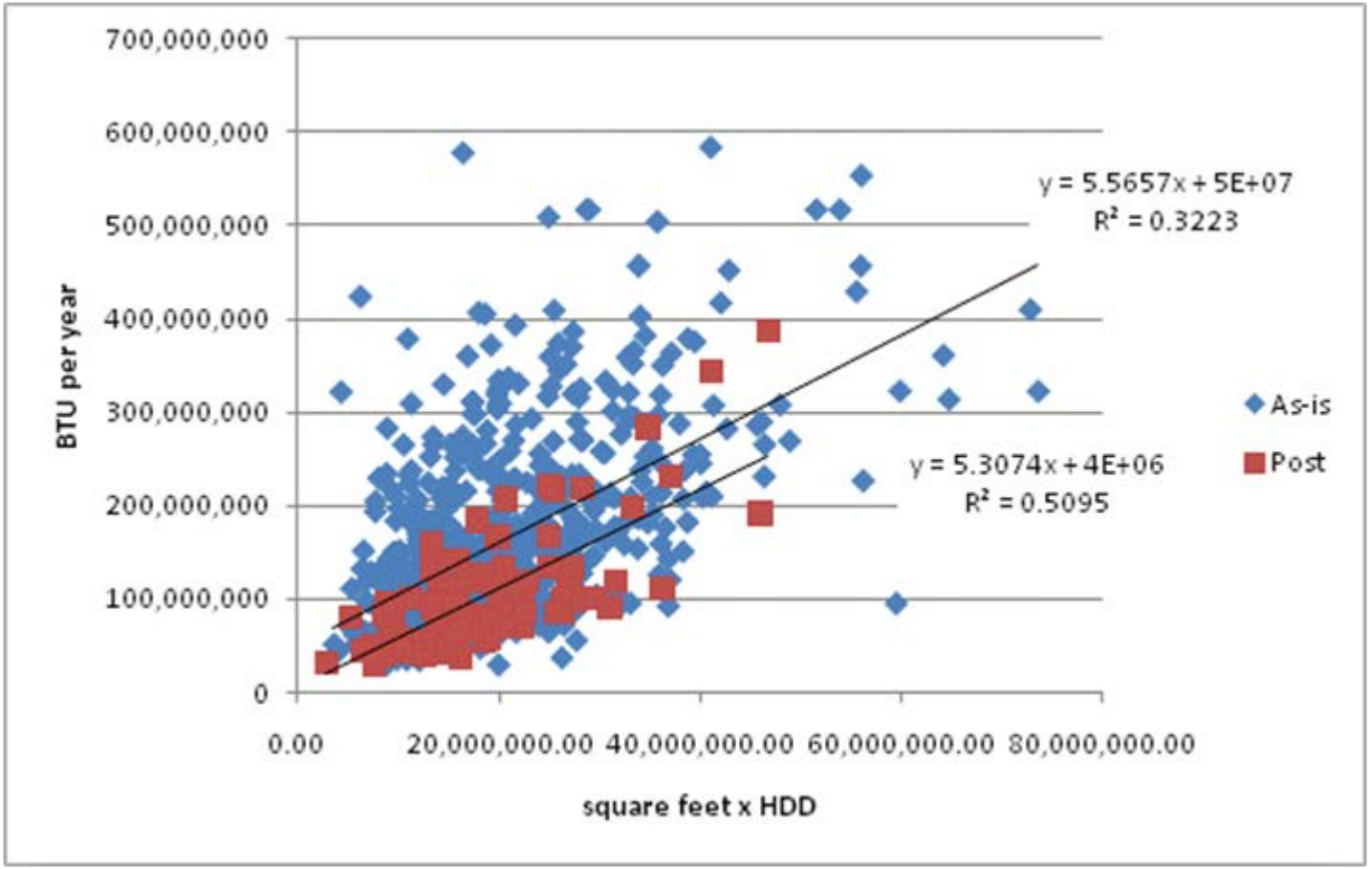
Why does it matter? Integrated Power-Energy-Storage-Usage Systems



Buildings

Transportation

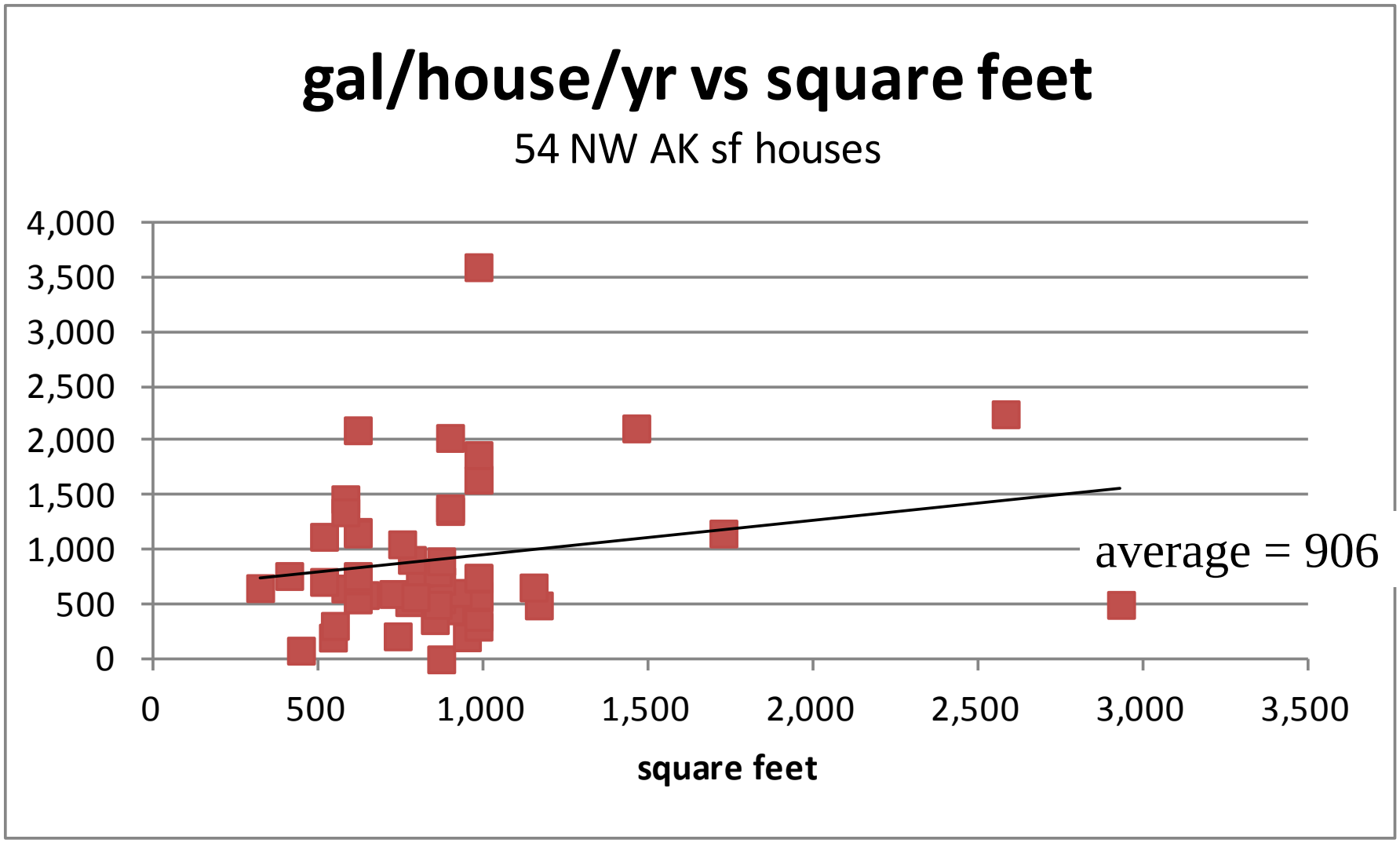
residential buildings: effect of residential retrofits



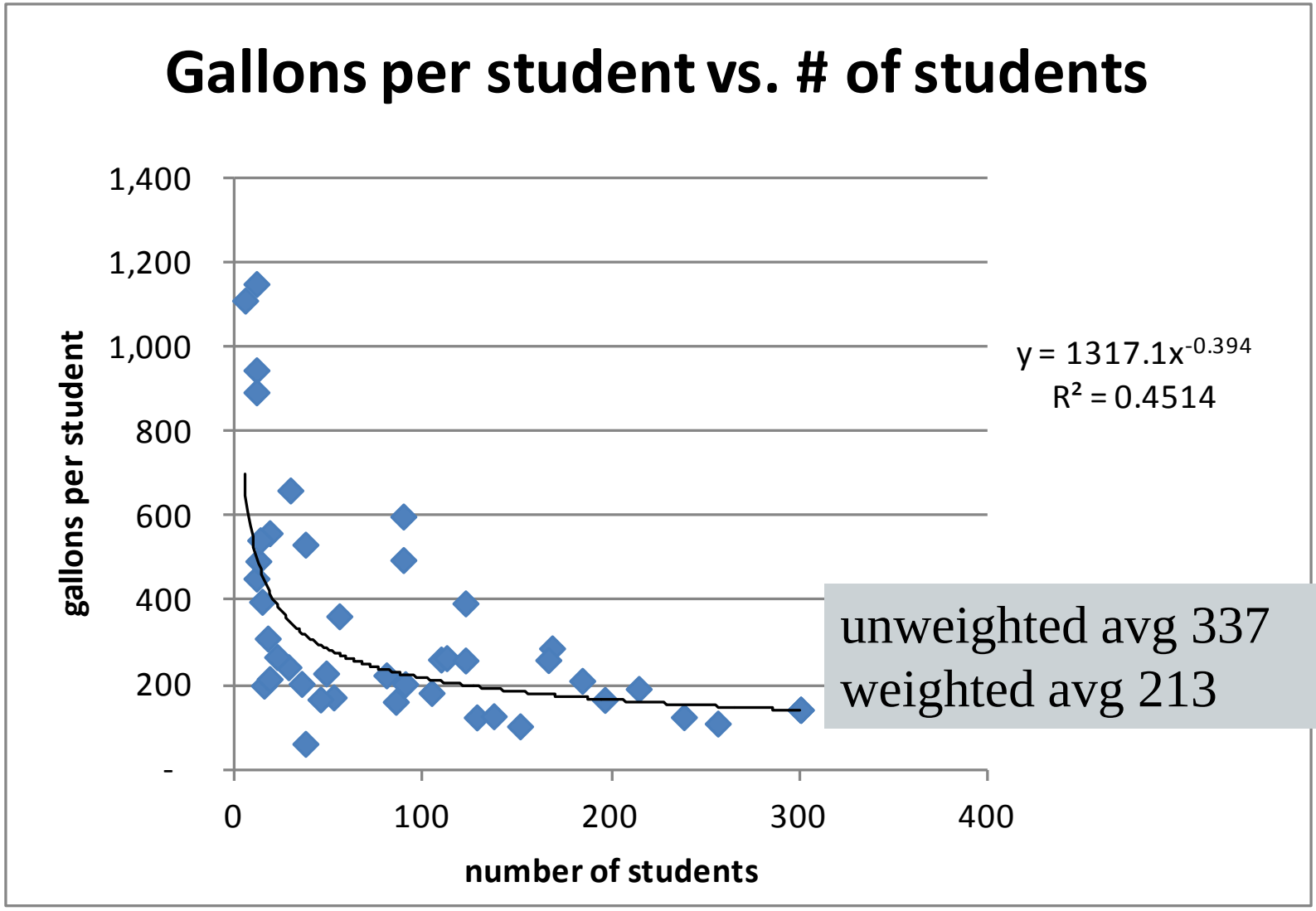
Pre sample 697

Post sample 97

residential buildings

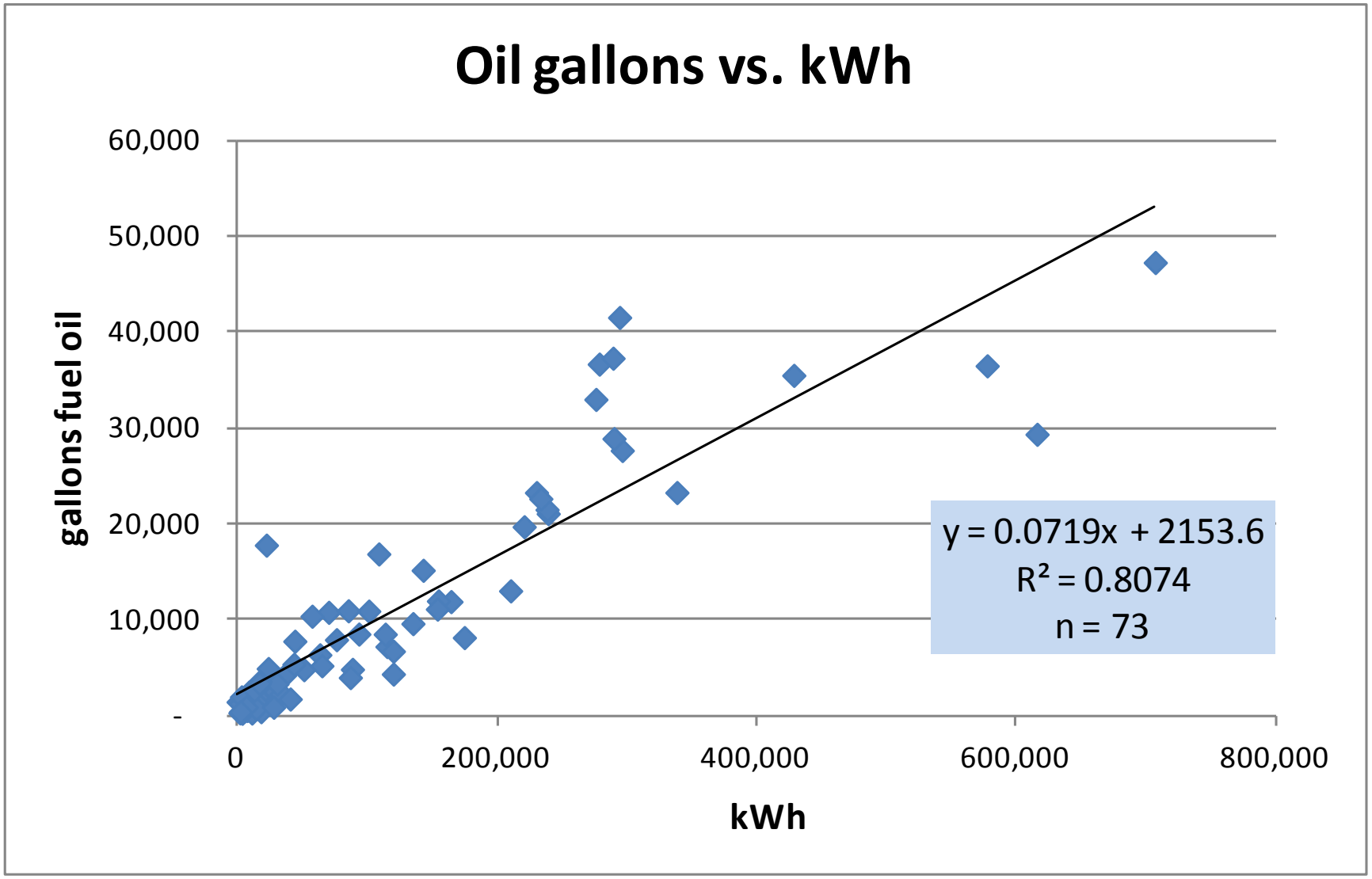


School heating fuel use



unweighted avg 337
weighted avg 213

Nonresidential heating fuel



trimmed sample of 73 mostly nonresidential REALS buildings

Model Demo…

General parameters

Community name		Iguigig	
Population	persons	60	
Start Year		2012	
Real discount rate	% per yr	4.0%	
Heating degree days base 65		16,000	
City for monthly HDD fractions		Dillingham	see "monthly HDD" tab for choices
Population growth	% per yr	1.0%	
Btu per gallon of fuel		134,000	common values 134,000 (#1) 138,000 (#2)

		residential	nonresidential	utility
Price of diesel fuel in Start Year	$/gallon	5.00	4.50	4.00
Price of gasoline in Start Year	$/gallon	6.00		

Inputs to electric load calculator

	Category Number: (Type a value 1-5	Description of Categories: 1	2	3	4	5
Median Household Income:	3	below 30,000	about 35,000	above 40,000	-	-
K-12 School:	2	Low	Average	High	-	-
Public Water System:	2	Level 2 Low	Level 2 High	Level 1 Low	Level 1 Med	Level 1 High
Health Clinic:	1	Local	Subregional	-	-	-
Communications:	1	Basic	Advanced	-	-	-

# of Small Businesses	1
# of Large Commercial:	0
# of Community Buildings:	1
# of Government Offices:	2
Other loads (usually 3-7%):	5%

Current housing stock

		house group Hgroup1	Hgroup2	Hgroup3	Hgroup4
label for group		single_old	single_new	multi	mobile
house_type (1=SF, 2=MF, 3=MH)		1	1	2	3
number of housing units		15	5	2	0
average square feet	FT2/yr	1,100	1,100	1,000	900

Choose 1 method for space heat intensity kbtu/FT2					
Choice of method (1, 2, 3, 4)		1	2	3	4
Enter required inputs for your method(s)					
1 Linear function of HDD					
input: post-retrofit? (1=yes, 0=no)		0	1	0	0
lookups for linear function	d_multifamily	0	0	1	0
	d_mobilehome	0	0	0	1
result of linear function	kbtu/FT2/yr	95.4	73.9	83.5	126.3
2 kbtu per FT2 by direct entry	kbtu/FT2/yr	0	75	0	0
(consult tables in equations tab)					
3 mmbtu per house per year	mmbtu/H/yr	0	0	100	0
(consult tables in equations tab)					
	kbtu/FT2/yr	0.0	0.0	100.0	0.0
4 engineering end use approach					
End use baseboard heat per SqFt	kbtu/FT2/yr	40.0	30.0	20.0	50.0
heater efficiency	%	75%	75%	75%	75%
fuel input to heater	kbtu/FT2/yr	53.3	40.0	26.7	66.7
Space heat intensity chosen:	kbtu/FT2/yr	95.4	75.0	100.0	66.7
Choose 1 method for hot water (dhw)					
Choice of method (1, 2)		1	1	1	1
1 average fuel mmbtu per house per yr		22.4	22.4	15.6	17.1
(consult tables in equations tab)					
2 average mmbtu per water heater		25.5	25.5	20.2	26.5
(consult tables in equations tab)					
Water heater mmbtu/H/yr chosen:	mmbtu/H/yr	22.4	22.4	15.6	17.1

Transportation

		snowmachine	boat	ATV / truck	Total
By residents					
1 average use per person per yr	gal/yr	169	83	76	328
result: gallons used	gal/yr	10,140	4,980	4,560	19,680
or					
2 number of machines		12	17	10	
average use per machine per yr	gal/yr	492	309	326	
result: gallons used	gal/yr	5,904	5,253	3,260	14,417
Choose method (1,2)		1	1	1	
Transportation use by residents	gal/yr	10,140	4,980	4,560	19,680
By community vehicles					
average use per person per yr	gal/yr	50	(estimate based on one study of Galena)		
Transportation use by community vehicles		3,000			

Electricity

Etc. - →→

		Units		Initial Value	Growth Rate	Year 2012	2013	2014
Existing electric loads								
	from Village Load Calculator							
	Residential	kWh		99,646	1.0%	99,646	100,643	101,649
	override							
	School	kWh		30,269	1.0%	30,269	30,572	30,878
	Commercial	kWh		26,133	1.0%	26,133	26,394	26,658
	Water / sewer	kWh		7,084	1.0%	7,084	7,155	7,227
	Government	kWh		38,203	1.0%	38,203	38,585	38,971
	Health Clinic	kWh		1,718	1.0%	1,718	1,735	1,752
	Communications	kWh		23,751	1.0%	23,751	23,988	24,228
	Other	kWh		11,340	1.0%	11,340	11,454	11,568
	override							
	subtotal from calculator			238,145		238,145	240,526	242,931
	multiplier adjustment			1.00		1.00	1.00	1.00
	Total existing	kWh		238,145		238,145	240,526	242,931
	override							
	New electric loads		**start year**	**value**	**growth**			
	New school example	kWh	2025	50,000	0.0%	0	0	0
nega-load:	wind turbines	kWh	2025	-10,000	0.0%	0	0	0
	New load 3	kWh	enter annual values at right			0	0	0
	Total New	kWh				0	0	0
	Total Electric Energy	kWh		**238,145**		**238,145**	**240,526**	**242,931**
	Load factor			0.54		0.54	0.54	0.54
	override							
	Peak load	kW		**50**		**50**	**51**	**51**
	Diesel Fuel use							
	Efficiency	kWh/gal		14.00	0.0%	14.00	14.00	14.00
	override							
	Gallons used	gal/yr		17,010		17,010	17,180	17,352

Buildings fuel use

			Units	Initial Value		Growth Rate		Year 2012	2013	2014
Residential heat										
House group 1		label:	single_old							
	number of houses			15		1.0%		15	15	15
	average size		FT2	1,100		0.0%		1,100	1,100	1,100
	fuel use intensity		kbtu/FT2/yr	95		0.0%		95	95	95
	fuel use per house		mmbtu/yr	105				105	105	105
	fuel use per house		gal/yr	783				783	783	783
House group 2		label:	single_new							
	number of houses			5		1.0%		5	5	5
	average size		FT2	1,100		0.0%		1,100	1,100	1,100
	fuel use intensity		kbtu/FT2/yr	75		0.0%		75	75	75
	fuel use per house		mmbtu/yr	83				83	83	83
	fuel use per house		gal/yr	616				616	616	616
House group 3		label:	multi							
	number of houses			2		1.0%		2	2	2
	average size		FT2	1,000		0.0%		1,000	1,000	1,000
	fuel use intensity		kbtu/FT2/yr	100		0.0%		100	100	100
	fuel use per house		mmbtu/yr	100				100	100	100
	fuel use per house		gal/yr	746				746	746	746
House group 4		label:	mobile							
	number of houses			0		0.0%		-	-	-
	average size		FT2	900		0.0%		900	900	900
	fuel use intensity		kbtu/FT2/yr	67		0.0%		67	67	67
	fuel use per house		mmbtu/yr	60				60	60	60
	fuel use per house		gal/yr	448				448	448	448
Total residential heat			gal/yr	**16,315**				**16,315**	**16,478**	**16,643**

Transportation

	Units	Initial Value	Growth Rate	Year 2012	2013	2014
Population		60	1.0%	60	61	61
Current use per person						
snowmachine	gal/person/yr	169		169	169	169
boat	gal/person/yr	83		83	83	83
ATV / truck	gal/person/yr	76		76	76	76
community vehicles	gal/person/yr	50		50	50	50
Index of vehicle-miles per person						
snowmachine		1.00	0.0%	1.00	1.00	1.00
boat		1.00	0.0%	1.00	1.00	1.00
ATV / truck		1.00	0.0%	1.00	1.00	1.00
community vehicles		1.00	0.0%	1.00	1.00	1.00
Index of fuel use per vehicle-mile						
snowmachine		1.00	0.0%	1.00	1.00	1.00
boat		1.00	0.0%	1.00	1.00	1.00
ATV / truck		1.00	0.0%	1.00	1.00	1.00
community vehicles		1.00	0.0%	1.00	1.00	1.00
Total fuel use						
snowmachine	gal/yr	10,140		10,140	10,241	10,344
boat	gal/yr	4,980		4,980	5,030	5,080
ATV / truck	gal/yr	4,560		4,560	4,606	4,652
community vehicles	gal/yr	3,000		3,000	3,030	3,060
Total fuel use for transportation		**22,680**		**22,680**	**22,907**	**23,136**

Cost

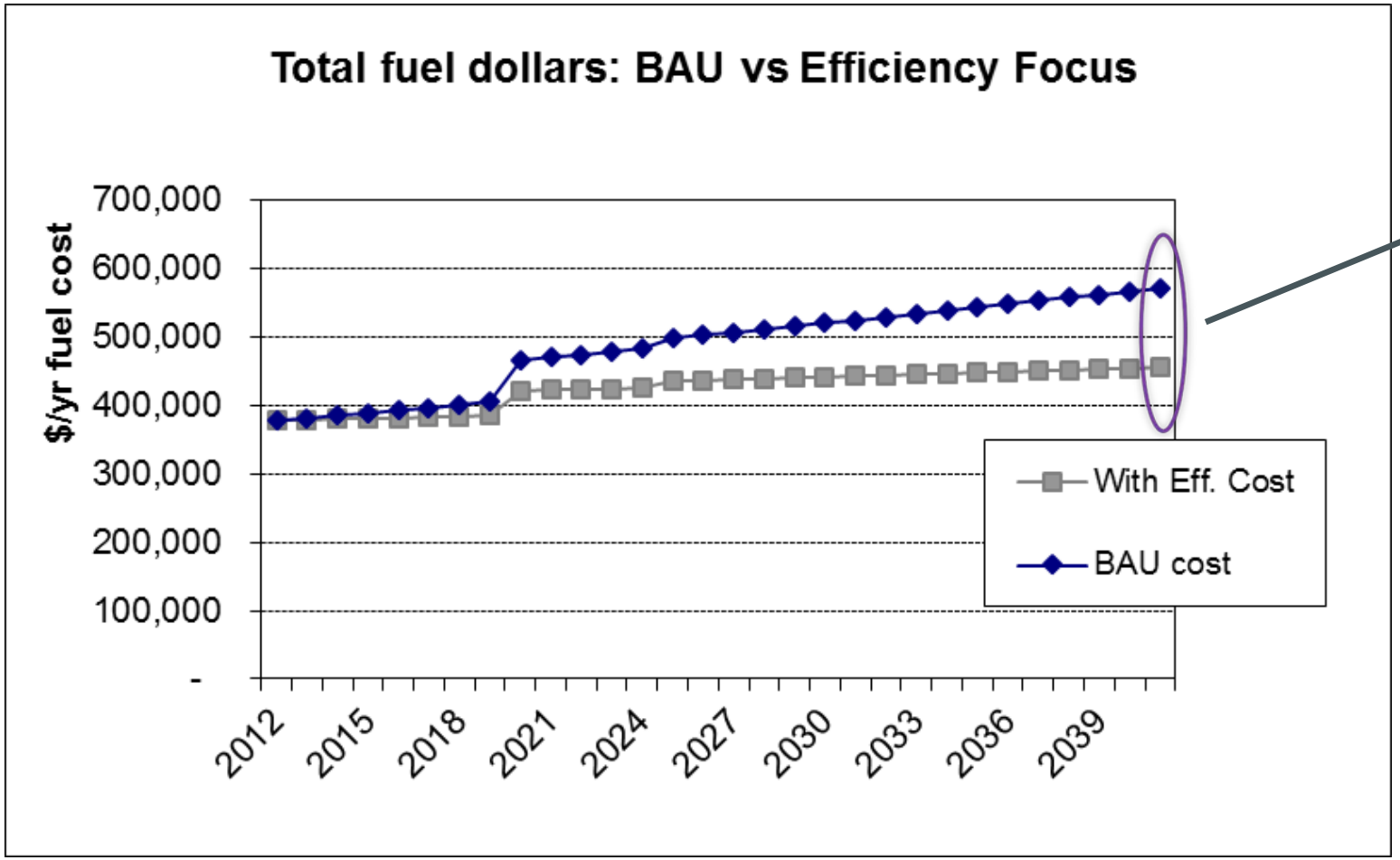
	Units	Initial Value	Growth Rate	Present value	Year 2012	2013	2014	2030	2040
Population		60	1.0%		60	61	61	72	79
Fuel prices									
residential heating	$/gal	5.00	0.0%		5.00	5.00	5.00	5.00	5.00
nonresidential heating	$/gal	4.50	0.0%		4.50	4.50	4.50	4.50	4.50
utility diesel	$/gal	4.00	0.0%		4.00	4.00	4.00	4.00	4.00
gasoline	$/gal	6.00	0.0%		6.00	6.00	6.00	6.00	6.00
Fuel Use									
Utility electricity		17,010			17,010	17,180	17,352	23,204	25,333
Residential heating		16,315			16,315	16,478	16,643	19,515	21,557
Residential hot water		3,576			3,576	3,612	3,648	4,278	4,725
Nonresidential buildings		16,460			16,460	16,624	16,791	32,288	34,348
Transportation		22,680			22,680	22,907	23,136	27,129	29,967
Total fuel use	gal/yr	**76,041**			**76,041**	**76,802**	**77,570**	**106,414**	**115,930**
Fuel use per person									
Utility electricity		284			284	284	284	323	320
Residential heating		272			272	272	272	272	272
Residential hot water		60			60	60	60	60	60
Nonresidential buildings		274			274	274	274	450	433
Transportation		378			378	378	378	378	378
Total fuel use per person	gal/person/yr	**1,267**			**1,267**	**1,267**	**1,267**	**1,483**	**1,462**
Fuel Cost									
Utility electricity	$/yr	68,041		1,409,022	68,041	68,722	69,409	92,816	101,331
Residential heating	$/yr	81,575		1,589,163	81,575	82,390	83,214	97,575	107,784
Residential hot water	$/yr	17,881		348,334	17,881	18,059	18,240	21,388	23,625
Nonresidential buildings	$/yr	74,070		2,041,668	74,070	74,810	75,558	145,298	154,567
Transportation	$/yr	136,080		2,650,988	136,080	137,441	138,815	162,772	179,801
Total fuel cost	$/yr	**377,646**		**8,039,175**	**377,646**	**381,423**	**385,237**	**519,849**	**567,109**
Fuel Cost per person									
Utility electricity	$/yr	1,134			1,134	1,134	1,134	1,293	1,278
Residential heating	$/yr	1,360			1,360	1,360	1,360	1,360	1,360
Residential hot water	$/yr	298			298	298	298	298	298
Nonresidential buildings	$/yr	1,234			1,234	1,234	1,234	2,025	1,950
Transportation	$/yr	2,268			2,268	2,268	2,268	2,268	2,268
Total fuel cost per person	$/yr	6,294			6,294	6,294	6,294	7,243	7,153

Possible focus on efficiency

- Residential buildings improve stock average kbtu/Ft2 by 1% per year
- New non-residential buildings 10% lower kbtu/Ft2
- Wind electricity (already starting in 2025) increases by 2%/yr thereafter
- Transportation fleet average fuel/VMT improves by 1%/yr

Cost

		Units	Initial Value	Growth Rate	Present value	Year 2012	2013	2014	2030	2040
Population			60	1.0%		60	61	61	72	79
Fuel prices										
	residential heating	$/gal	5.00	0.0%		5.00	5.00	5.00	5.00	5.00
	nonresidential heating	$/gal	4.50	0.0%		4.50	4.50	4.50	4.50	4.50
	utility diesel	$/gal	4.00	0.0%		4.00	4.00	4.00	4.00	4.00
	gasoline	$/gal	6.00	0.0%		6.00	6.00	6.00	6.00	6.00
Fuel Use										
	Utility electricity		17,010			17,010	17,090	17,170	20,634	21,453
	Residential heating		16,315			16,315	16,313	16,312	16,286	16,269
	Residential hot water		3,576			3,576	3,576	3,575	3,570	3,566
	Nonresidential buildings		16,460			16,460	16,624	16,791	27,428	29,488
	Transportation		22,680			22,680	22,678	22,675	22,639	22,617
	Total fuel use	gal/yr	**76,041**			**76,041**	**76,281**	**76,523**	**90,557**	**93,394**
Fuel use per person										
	Utility electricity		284			284	282	281	288	271
	Residential heating		272			272	269	267	227	205
	Residential hot water		60			60	59	58	50	45
	Nonresidential buildings		274			274	274	274	382	372
	Transportation		378			378	374	370	315	285
	Total fuel use per person	gal/person/yr	**1,267**			**1,267**	**1,259**	**1,250**	**1,262**	**1,178**
Fuel Cost										
	Utility electricity	$/yr	68,041		1,305,369	68,041	68,358	68,679	82,535	85,813
	Residential heating	$/yr	81,575		1,408,952	81,575	81,566	81,558	81,428	81,347
	Residential hot water	$/yr	17,881		308,833	17,881	17,879	17,877	17,848	17,831
	Nonresidential buildings	$/yr	74,070		1,810,736	74,070	74,810	75,558	123,428	132,697
	Transportation	$/yr	136,080		2,350,366	136,080	136,066	136,053	135,835	135,699
	Total fuel cost	$/yr	**377,646**		**7,184,256**	**377,646**	**378,680**	**379,725**	**441,075**	**453,387**


Total fuel dollars: BAU vs Efficiency Focus
$/yr fuel cost
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
With Eff. Cost
BAU cost

21 %